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PHOTOPRODUCTION DU MESON π^+ SUR L'HYDROGÈNE A
180° ENTRE 450 MeV ET 3 GeV

Article Principal

PHOTOPRODUCTION OF POSITIVE PIONS AT 180°
FROM 0.22 GeV TO 3.1 GeV

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PHOTOPRODUCTION OF POSITIVE PIONS AT 180°
FROM 0.22 GeV to 3.1 GeV

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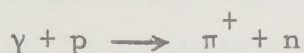
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Abstract : The π^+ photoproduction cross section in hydrogen has been measured at 180° for photon energies from 0.22 to 3.1 GeV by detecting the pion in the backward direction. The statistical accuracy of the measurements varies typically from 3 % to 10 % depending on the energy. The data are compared with other recent experimental results and predictions of phenomenological theories.

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This letter describes two experiments on the reaction :



in which the pions were detected near 180° over a photon energy range from 220 MeV to 3.1 GeV. The center of mass angular acceptance was typically from 177.5° to 180° . The first experiment, performed at the Orsay linear electron accelerator, measured differential cross sections in the vicinity of the $\Delta(1236)$ up to 440 MeV incident photon energy. In the second experiment, the measurements were extended at the Daresbury electron synchrotron from 450 MeV up to the region of the $\Delta(2420)$. Both experiments combine good statistics and energy resolution over most of the photon energy range.

Figure 1 shows the layout of the two experiments. In both cases we used a bremsstrahlung photon beam, the same hydrogen target system (only the target cell was different) and the same spectrometer. The principal differences concern the beam ditching procedure and the particle detectors.

In the low energy experiment, the electron beam was swept by the spectrometer itself. This allowed the radiator-to-target distance to be kept as short as possible, thereby admitting radiators of reasonable thickness (~ 0.04 radiation length) without excessive beam spot enlargement due to multiple scattering of the low energy electron beam in the radiator. Pions were detected in a four scintillation counter telescope, accepting particles within a 3.62 % fractional momentum bin. At the lower momenta, copper absorbers were remotely positioned between the last two scintillators of the telescope to separate pions from muons according to range.

For the high energy experiment, it was necessary to sweep the electron beam by a separate magnet, the background created by the electron beam going through the spectrometer being too high. In addition the vacuum system was extended downstream from the scattering chamber through a second sweeping magnet which prevented charged particles produced in the nearby beam-stop from entering the magnetic channel of the spectrometer. The particles were counted by a three scintillator telescope accepting most of the momentum range analysed by the spectrometer ($\sim 7\%$), and the particle trajectory in the image region of the spectrometer was determined by two spark chambers with current division readout⁽¹⁾. The momentum of the detected pion was measured with a resolution of 0.1% FWHM, and the angle of emission at the target was determined within ± 0.02 rd. The spark chambers were connected to a Varian 622/I computer which provided a simplified on-line computation of momentum and angles, and a display of the spectra, as well as storage on magnetic tape of the counter pulse heights and spark chamber signals from each event.

The major apparatus common to both experiments was "Bacchus", a 180° double focussing spectrometer with 0.7 m mean radius and 430 MeV/c maximum analysed momentum. Baffles inside the vacuum chamber defined the accepted solid angle. First order magnet theory, ray tracing through field maps in the median plane, and α -ray measurements at an effective momentum of 95 MeV/c were used to study transmission characteristics of the spectrometer. These methods gave consistent results, of which the two most important are a solid angle of 6.81 ± 0.14 msr and an inverse dispersion of 27.2 ± 0.27 mm/%.

The electron beam intensity was measured with an error less than 1% by secondary emission monitors, which were calibrated frequently against a Faraday cup located on the photon beam line downstream from the spectrometer. The radiator thickness being

known to better than 1 %, the major uncertainties on the photon spectrum arise from the theoretical calculation of the bremsstrahlung and are estimated to be ± 1 %. During data taking empty and full target runs were regularly alternated to check the stability of the measurements

In both experiments, the major backgrounds were pions, protons, and some positrons produced by the passage of the incident photon and/or electron beam through the spectrometer and arriving by the magnetic channel. The limited range of the protons permitted their absorption before reaching the end of the telescope. Separate measurements using Cerenkov counters showed that positron production in the hydrogen was negligible. Pions from multiple production were kinematically excluded. Thus the particles produced in the hydrogen were assumed to be pions from single photoproduction and muons from pion decay. In the Daresbury experiment, collimators downstream from the radiators were used to reduce the halo around the photon beam which produced the major part of the background. We verified that no significant part of the photon beam was lost in the collimators by measuring the transmission of the electron beam to the Faraday cup as a function of radiator thickness with all the magnets downstream from the radiators switched off. Over the whole energy range, the full to empty target ratio was always ≥ 2 .

The calculation of the cross-section from the raw data includes the corrections listed in table 1. Corrections for strong interactions in the target and absorbers yield rather large errors because of the poorly known cross sections involved. The effects of pion decay, muon contamination and baffle penetration were computed by the Monte Carlo technique. For the low momentum points of the Orsay experiment the computed contamination agreed with the variable absorber measurements

when the latter were corrected for muons stopping in the absorber. We often measured the yield beyond the tip of the bremsstrahlung spectrum. It was negligible except at the highest energies of the Daresbury experiment, where the rate was about 5 % of the yield on the shoulder of the spectrum ; this is consistent with our Monte Carlo calculations of the effect due to muon contamination and baffle penetration.

Incident electron energies from 372 MeV to 694 MeV were used to measure the cross section at photon energies every 20 MeV from 220 MeV to 440 MeV at Orsay. At Daresbury, data were taken at 8 electron beam energies from 720 MeV to 3160 MeV and 16 settings of the spectrometer current so as to cover completely the photon energy range from 450 MeV to 3160 MeV. At the highest energies the observed position of the bremsstrahlung tip in momentum disagreed slightly with that predicted from the nominal incident beam energy, but the k/E cutoff of 0.95 used in the data shown here obviates this problem. The data are plotted in figs. 2 and 3 as a function of laboratory photon energy. Points from different spectrometer settings are in agreement in the regions of overlap. The vertical error bars are due to statistics only. The horizontal separation of the points is at least two estimated standard deviations in the gaussian (major) contribution to the photon energy resolution. The data up to 1.1 GeV are shown in fig. 2. The points from 220 MeV to 440 MeV are those measured at Orsay. The solid line is the fit of WALKER⁽²⁾. The prediction is significantly low on the high side of the first resonance. This is also true for the theories of refs 3-5. The theory of SCHMIDT⁽⁶⁾ fits the high side of the resonance but is slightly too high and broad.

Above the Δ (1236) up to $k \simeq 900$ MeV the data lie somewhat above WALKER's fit, but the shape is generally compatible. The shape of the gentle narrow bump at 700 MeV is similar to that found by HAND and SCHAERF⁽⁷⁾, but their points lie about 40 % lower than ours⁽⁸⁾. This structure, occurring at the threshold for $\gamma + p \rightarrow \eta + p$, is perhaps the η cusp which is visible because of the large decay width of the $S_{11}(1535)$ into ηN ⁽⁹⁾.

For $k \simeq 950$ MeV the measurements show a bump not evident in WALKER's fit. The measurements of THIESSEN⁽⁸⁾ at $\theta^* \simeq 166^\circ$ do not show this structure, but do agree with our values on either side of this bump.

In fig. 3 we show the data for the entire energy range of the experiment and indicate results from some other experiments. Three recent experiments on $180^\circ \pi^+$ photoproduction have been reported in preliminary form. The data of FUJII et al.⁽¹⁰⁾ cover an energy range from 270 MeV to 1170 MeV. These data agree quite well with ours up to $k \simeq 1000$ MeV ; above this energy our data decrease faster than FUJII's, the discrepancy reaching a factor of 2 at 1170 MeV. The data of FISCHER et al.⁽¹¹⁾ extend from 590 MeV to 1290 MeV. Below 1 GeV, these data are lower than ours by about 8 % which is consistent with the systematic errors claimed in both experiments, and agree with our data on the slope above 1000 MeV. The paper of EKSTRAND et al.⁽¹²⁾ presents data from 700 MeV $< k < 7$ GeV. These data tend to coincide with the cross-sections at $\theta^0 = 168^\circ$ of THIESSEN⁽⁸⁾ and ALVAREZ⁽¹³⁾ except that near 1700 MeV their values lie near to ours.

From 1 GeV to 1.6 GeV we observe a sharp but slightly structured decrease in the cross section. The dip at 1.75 GeV appears to be an extension of the tendency of the ALVAREZ cross sections in this energy region to decrease as the pion angle increases from 145°

to 167° . In the angular range of our experiment ($\pm 1.8^\circ$) no marked angular dependance was observed. The 1.75 GeV dip is followed by a broad bump centered at about 2.2 GeV. The $180^\circ \pi^0$ photoproduction data of BUSCHORN et al.⁽¹⁴⁾(fig. 3) show a somewhat similar structure (dip followed by a broad bump) but the energies at which these structures appear are higher by about 300 MeV than in the π^+ data. The π^0 structures appear close to the energies of the G 17 (2190) and Δ (2420) indicating that these resonances might dominate this energy region in a rather simple way. The combination of the π^+ and π^0 data shows that the situation is more complex, and the disentanglement of the effects of the various nucleon isobar contributions probably requires a partial wave analysis of angular distributions, as in the 2nd and 3rd resonance regions.

At photon energies from 4 GeV to 15 GeV, the data of ANDERSON et al.⁽¹⁵⁾ for reaction (1) indicate that the quantity $Y = k^3 \frac{d\sigma}{du} (\mu\text{b-GeV-c}^2)$ as a function of u is independant of k , for $1.6 < u < 0.04 (\text{GeV/c})^2$. As u increases, Y increases to a maximum of about 3 near $u = 0$ although it is not absolutely clear that Y is dropping for $u > 0$. Our data for $k > 2.4$ GeV cover a range of u values from 0.11 to 0.14, and in this interval we find Y increasing from 1.3 to 4.5. Combined with the large angle data of ALVAREZ et al., our data show that between 2.4 and 3.1 GeV, Y is not independent of k . The extrapolation to this energy region of Regge fits to the high energy data⁽¹⁶⁾ shows that the measured slope of the cross section is much too high to be explained by a u channel exchange of single Regge trajectories, indicating that up to 3.1 GeV the reaction is dominated by s channel exchange of baryonic resonances.

More complete descriptions of this work will be published elsewhere. In the meantime, table of values of the cross sections can be obtained from one of the authors.

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TABLE 1

EFFECT	ORSAY		DARESBUY	
	Corrections	error	corrections	error
Pion decay in flight	50-25	1	25-15	1
Muon contamination	12-9	10	4-3	15
Momentum acceptance variation due to energy loss in target	20-2	2	1-0	
Interactions of pions in target	2-10	30	8-1	30
Pion interactions in coun- ting system	1-2	30	13.5	30
Solid angle variation : due to baffle penetration	0		0-3	30
due to field shape varia- tion	0		0-4	50
counting rate and efficien- cy	1-6	30	6-13	10

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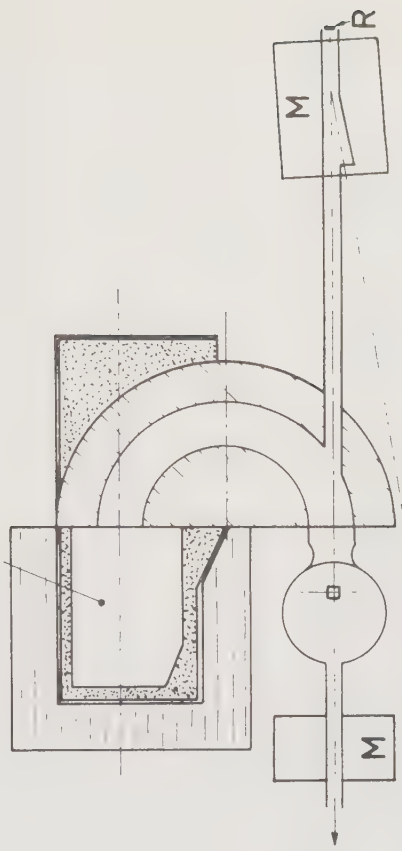
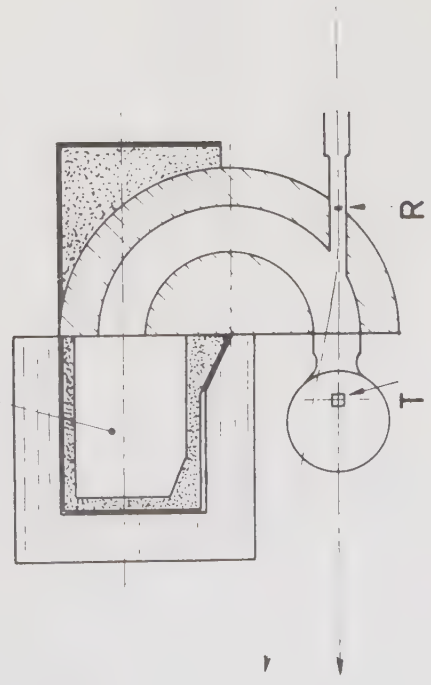
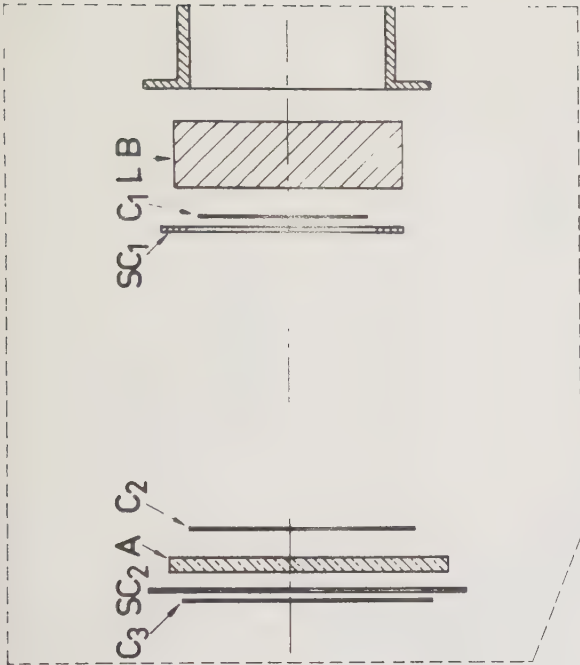
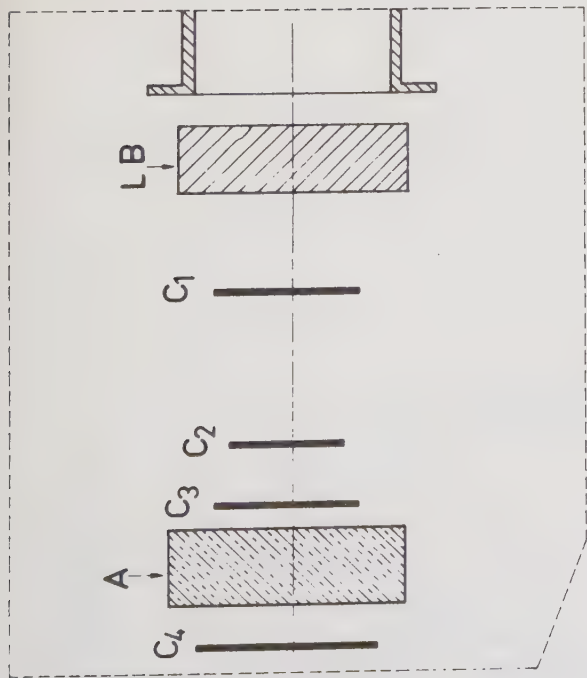


Fig 1

a)

b)

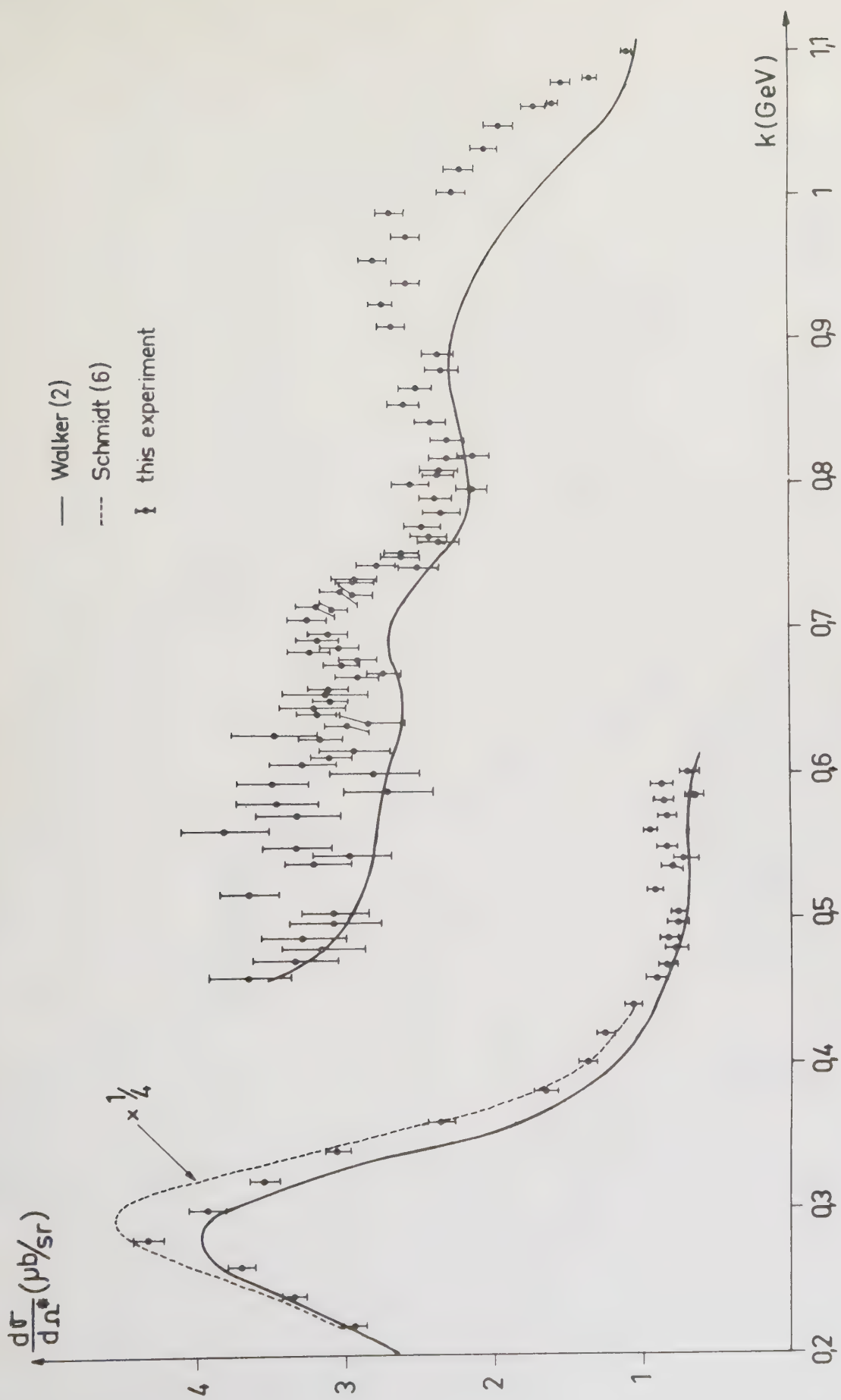


Fig 2

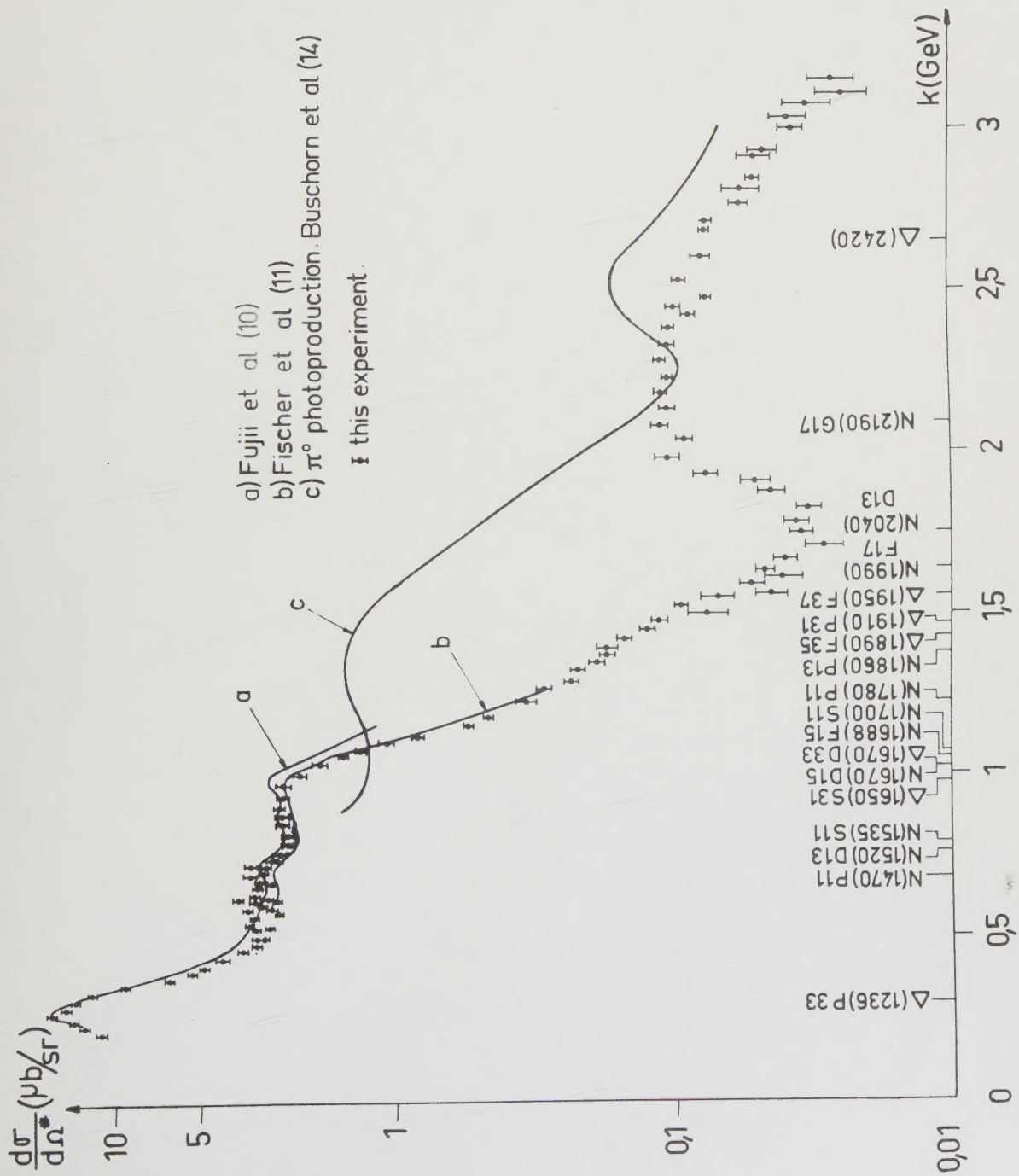


Fig 3

